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Defibrillation electrode arrangement

Description

The invention concerns a defibrillation electrode arrangement of the kind set forth in the classifying portion of claim 1.

Implantable automatic defibrillators are increasingly used in relation to patients with cardiac disrhythmia which can lead to the sudden occurrence of ventricular fibrillation and which cannot or cannot be reliably the subject of therapy by medication. In many cases such patients additionally require pacemaker support for their cardiac activity so that more specifically also combination units with a cardiac pacemaker have come into use to a certain extent.

Because of the lower level of operating expenditure and risk electrode arrangements which are increasingly gaining ground in comparison with the earlier subcutaneous surface electrodes are those arrangements in which at least a part of the electrodes is arranged on a catheter or electrode line body which is to be endocardially laid by a transvenous procedure. Those electrode arrangements, in conjunction with pacemaker/defibrillator combination units, additionally afford the advantage that a part of the electrodes can be used both as pacemaker

and also as defibrillation electrodes or at any event sensing, pacemaker and defibrillation electrodes can be formed on one and the same electrode line, thus substantially doing away with the need to lay a plurality of separate catheters.

An early electrode arrangement in which subcutaneous electrodes are totally eliminated and which includes an electrode to be arranged at a wall position in the ventricular apex and an electrode to be arranged in the superior vena cava is described in US No 3 942 536.

US No 4 727 877 describes inter alia an endocardial electrode arrangement which is intended for low-energy defibrillation by means of pairs of stimulation pulses and which includes two pairs of electrodes comprising a total of three cylindrical electrodes of an elongated configuration, of which one is arranged in the apex of the right ventricle, a second is arranged in or on the sinus coronaris and the third is arranged in the vena cava superior. The arrangement is implemented on two separate electrode lines.

In an arrangement which is described in WO 92/09329 and which is to be screwed into the ventricle, besides a tip electrode the assembly has three elongated electrode portions on a single line which is used together with a sinus electrode or a subcutaneous plate electrode. The provision of a plurality of electrode portions on the endocardial line serves primarily for implementation of a modular principle for hearts of smaller or larger sizes.

EP 0 522 693 A1 describes an arrangement including two separate endocardial electrode lines and a subcutaneous surface electrode, specifically for atrial defibrillation, in a plurality of different circuitry configurations.

WO 94/03233 proposes an electrode arrangement both for ventricular and also for atrial defibrillation, which, on a first line to be laid in the right ventricle, includes an elongated, coil-shaped defibrillation electrode and two sensing and pacemaker electrodes arranged on a

second line to be laid in the atrium, as well as the defibrillator housing as a second defibrillation electrode.

The known defibrillation electrodes are either still relatively limited in terms of the functions which they can perform - if they are of a simple structure and are easy to implant - or - if they are to perform more complex functions - they are of a complicated structure and expensive to implant.

The object of the invention is therefore that of providing a defibrillation electrode arrangement of the kind set forth in the opening part of this specification, which while being of a simple structure and easier to implant is suitable for the implementation of a wide range of different functions.

That object is attained by an arrangement having the features of claim 1.

The invention embraces the notion of providing a substantially universal electrode arrangement for the implementation of ventricular and also atrial defibrillation (or two-chamber defibrillation) and the associated sensing function of an automatic defibrillator and also for the implementation of sensing and stimulation functions of a pacemaker combined with the defibrillator, with a single endocardial electrode line. Such an arrangement is possible using the principle of the focused stimulation pulse field which is produced between a non-wall-position (floating) ventricular defibrillation electrode and a counterpart electrode which is positioned in such a way as to be adapted to its specific configuration and spatial position. That permits the specific and targeted establishment of a suitable defibrillation region in the stimulatable cardiac tissue even when the position of the electrode line is fixed in a portion-wise manner (more especially in the atrium) for the implementation of additional functions by way of one or more additional electrodes.

In a preferred variant, the second defibrillation electrode - besides the first defibrillation electrode arranged on the electrode line in the right

ventricle - is formed by an extracardially arranged surface electrode, in particular at least one housing portion of the defibrillator (which is to be suitably positioned for that purpose). Use of the unit housing as a counterpart electrode has the particular advantage that there is no need for the implantation of an additional electrode.

In a second variant, the second defibrillation electrode is formed by a coil-shaped electrode which is adapted to be arranged in the vena cava superior and which in particular is also arranged on the single electrode line. The closer proximity to the first electrode and the fact of being independent of the implantation position of the defibrillator permit in this case higher stimulation field strengths and particularly easy displacement of the defibrillation excitation zone into the atrial region of the cardiac tissue and thus atrial defibrillation. Arranging the coil electrode in the vena cava inferior or in the sinus coronaris is also possible to achieve specific geometries in respect of the stimulation field and thereby predetermined localization effects for the defibrillation zone in the wall of the heart.

Both these variants can also be combined in such a way that - in addition to the vessel electrode as the second electrode - the arrangement has as the third defibrillation electrode an extracardially arranged surface electrode which again is formed in particular by the housing of the defibrillator. The first and second defibrillation electrodes are connected to outputs of the defibrillator and in the operating state are of different polarities with respect to the third electrode and the three defibrillation electrodes are spatially arranged relative to each other in such a way that formed between them is a spatially distorted dipole field with an increased potential gradient above the defibrillation threshold in a region of the wall of the heart, with a defibrillator output voltage which is beneath the defibrillation threshold. A particularly advantageous arrangement is one in which the equipotential lines which are formed entail a maximum curvature in the region of the wall of the heart.

For accurate positional setting the electrode line can have spacer means which support it against the wall of the heart after insertion into the ventricle. In order to ensure easy insertion of the line the spacer means must be spreadable away from the body of the line - in a per se known configuration - after termination of the implantation operation. Desirably they should also be extracorporally adjustable in such a way that the position of the first defibrillation electrode is variable relative to the wall of the heart after insertion of the electrode line.

An embodiment which is particularly suitable for combined pacemaker/defibrillator arrangements provides that, disposed in the region of electrode line which comes to lie in the ventricle after insertion into the heart is a further electrode beside the first defibrillation electrode in the distal end portion of the electrode line. The further electrode can be connected as the first and the defibrillation electrode can be connected as the second ventricular sensing and/or pacemaker electrode, to the defibrillator or a combined pacemaker/defibrillator respectively. If the distal electrode is intended to be used as a sensing electrode, it is preferable for it to be in the form of tip electrode, in particular with means for fixing in the wall of the heart.

In an arrangement which is desirable both for an automatic defibrillator and also for a combination of defibrillator and dual-chamber pacemaker, two further electrodes can be arranged on the electrode line proximally from the first defibrillation electrode in such a way that after insertion they lie in the atrium, in particular in the upper region thereof.

At least one of those atrial electrodes - preferably the proximal electrode - is then connected as a first sensing and/or pacemaker electrode to the defibrillator or a combined pacemaker/defibrillator. In a bipolar arrangement of the sensing or stimulation portion of the electrode arrangement, both atrial electrodes are connected as first and second sensing and/or pacemaker electrodes in a bipolar circuit to the defibrillator or combined pacemaker/defibrillator respectively.

In a preferred unipolar arrangement the unit housing serves especially as a sensing reference electrode of the defibrillator or as an indifferent sensing and stimulation electrode of the pacemaker part. As an alternative thereto the coil-shaped electrode which is adapted to be arranged in the vessel near the heart can be connected as a sensing and/or pacemaker reference electrode to the defibrillator or combined pacemaker/defibrillator.

In an embodiment which affords a particularly wide range of possible variations in terms of the configuration of the stimulation field, the first defibrillation electrode has a plurality of electrode portions which are insulated relative to each other and which can be individually connected to the defibrillator. The electrode portions on the one hand can desirably be in the form of circular ring segments of a generally annular defibrillation electrode, and on the other hand also in the form of individual rings which are insulated from each other and possibly spaced and which are arranged in a row in the longitudinal direction of the electrode line. In these embodiments, individual electrode portions or also a group thereof can be specifically connected to the output of the defibrillator in order to achieve a desired position and extent of the defibrillation zone in the wall of the heart.

In addition at least one of the defibrillation electrodes, especially the first one which is arranged in the ventricle, may have a porous surface with a fractal surface structure, which increases the size of the active electrode surface area by at least two orders of magnitude in comparison with the value arising out of the basic geometrical shape of the electrode, thereby entailing a considerable reduction in impedance.

The heart wall contact required for reliability of functioning of the atrial electrode or electrodes as a sensing electrode or electrodes is advantageously achieved by the electrode line having a portion which is disposed in the atrium in the operative state and which is curved in a V-like configuration and which is formed from two limbs which meet at an

acute angle and which each include an obtuse angle with the respectively adjoining portions of the electrode line. At least one sensing and/or pacemaker electrode is desirably arranged substantially at the point at which the limbs meet; however - if the electrode line has two atrial electrodes - it is also possible for both electrodes to be arranged near that point. This advantageous form of the electrode line is achieved by means for producing a biasing force (for example a suitably pre-bent spring or a portion comprising a shape memory alloy) whose effect is removed by the insertion of a guide wire whereby the electrode line is straightened for the insertion operation, or occurs automatically when the line experiences a rise in temperature, in the body.

Advantageous developments of the invention are characterized in the appendant claims or are set forth in greater detail hereinafter together with the description of the preferred embodiment of the invention, with reference to the drawings in which:

Figure 1 diagrammatically shows a defibrillation electrode arrangement in accordance with an embodiment of the invention in the implanted state,

Figure 2 diagrammatically shows the electrode line of a defibrillation electrode arrangement in accordance with a second embodiment of the invention in the implanted state,

Figure 3 diagrammatically shows a defibrillation electrode arrangement in accordance with a third embodiment of the invention in the implanted state,

Figures 4 through 6 each diagrammatically show respective portions of the electrode line of defibrillation electrode arrangements in accordance with further embodiments of the invention,

Figures 7a and 7b show the electrode line of Figure 1 (a) in the state within inserted guide wire and (b) in the shape in the operating state, and

Figures 8a through 8e are diagrammatic views showing the principles of alternative configurations of the connection of the individual electrodes of defibrillation electrode arrangements in accordance with embodiments of the invention to an implanted defibrillator or combined defibrillator/cardiac pacemaker.

Figure 1 is a partly sectional view of a heart 2 with an intracardially implanted defibrillation electrode arrangement connected to an implanted defibrillator or combined defibrillator/cardiac pacemaker (not shown).

The electrode arrangement has an electrode line 1 which is passed through the vena cava superior 6 through the right atrium 4 into the apex region of the right ventricle 3 and which is subdivided into a proximal line portion 1.1 (which after implantation is in the atrium) and a distal line portion 1.2 (placed in the ventricle). The distal line portion 1.2 has at its free end a tip electrode 8 and at a short spacing proximally therefrom a ring electrode 9. Depending on the purpose of use and the nature of the cardiac rhythm correction unit connected to the line, those electrodes 8, 9 are intended in per se known manner in particular for the detection of heart action potentials and/or for ventricular pacemaker stimulation.

In the implanted state as illustrated the central line portion 1.1 is of an arcuate configuration in the form of a "V". That shape is achieved by a mechanical biasing effect which is applied in a portion-related manner to the electrode line 1 by means (not shown) such as the incorporation of a memory metal or a pre-bent spring. The central portion 1.1 of the line 1 can be converted into a substantially straightened shape, as is required for the implantation procedure, by a guide wire which extends in the interior of the line 1 during the implantation procedure (see in that respect Figures 7a and 7b). The V-shaped portion is directed from the wall of the vena cava superior 6 to the left-hand wall of the right atrium 4 and there contacts the myocardium. Provided in the central line portion 1.1 are two ring electrodes 10, 11 which also serve to detect heart action potentials and/or for atrial stimulation. The electrode 10 is arranged at the zenith 12

of the arcuate configuration while the electrode 11 is disposed proximally therefrom.

Disposed in the distal portion 1.1 of the electrode line - proximally from the electrodes 8, 9 - is an elongated coil-shaped defibrillation electrode 13. Disposed opposite same outside the heart, more specifically in the epicardial space near the vena cava inferior 7, is a counterpart defibrillation electrode 14 with separate feed line 14a, the electrode 14 being formed in per se known manner as a mesh-type or grid-type surface electrode. The coil electrode 13 is disposed in a region of the line 1, which is in the ventricle without touching the wall of the heart (in floating relationship). When a defibrillation pulse is outputted onto the line 1, an electrical shock pulse field is formed between the electrodes 13, 14. By virtue of that shock pulse field, a defibrillation zone which is in the form of a strip or a ring (depending on the extent of the counterpart electrode 14) is formed in the region D of the wall of the ventricle 3, through which the shock pulse field passes with a sufficiently high field strength (above the defibrillation threshold). The extent and the configuration of the defibrillation zone are controllable by way of the electrode configuration, besides the output voltage of the defibrillator.

The Figure diagrammatically shows that, at the proximal end of the portion of the electrode line 1 shown in the Figure, it has five individual electrode feed lines 1a through 1e, by way of which the electrodes 8 through 11 and 13 can be connected to the defibrillator or defibrillator/cardioverter. It will be appreciated - as will also become clear from the description hereinafter - that some of the feed lines 1a through 1e may currently be unconnected, depending on the specific operating state of the arrangement.

The individual electrodes can be produced in per se known manner and from known materials. In that respect, a porous surface structure which is achieved by a specific form of process implementation with a gaseous phase coating procedure (sputtering), and having a fractal

surface structure which increases the active electrode surface area by at least two orders of magnitude in comparison with the surface arising out of the basic geometrical shape of the electrode results in a advantageous marked increase in the interface capacitance with respect to the adjacent body tissue or the surrounding body fluid and thus a reduced effective electrode resistance. In this case iridium - for example sputtered onto a titanium support - can advantageously be used as the surface material here.

In regard to the function - which is the primary one in terms of the function of the arrangement according to the invention - of reliably effective, energy-efficient and tissue damage-eliminating transmission of defibrillation energy to the stimulatable cardiac tissue, a suitable shape, which is possibly tailor-made for the patient, dimensioning and arrangement of the electrodes 13 and 16 relative to each other is an aspect of crucial significance in terms of achieving an advantageous configuration in respect of the defibrillation pulse field. In that respect, the coil electrode 13 is advantageous insofar as it can easily assume a curved configuration and thereby permits easy "focusing" of the field onto given regions of the myocardium. In a specific embodiment it can also be variable in length whereby the field strength and configuration - in conjunction with the dimensioning and placement of the surface electrode 16 - are additionally controllable.

Figure 2 diagrammatically shows an electrode line 1' which is modified in comparison with Figure 1. The parts which are the same as in Figure 1 are denoted by the same reference numerals as those used therein and will not be described once again hereinafter.

In the present embodiment, the distal sensing and stimulation electrodes intended to be arranged in the ventricular are omitted so that the electrode line also only includes three feed lines 1a' through 1c' for the remaining three electrodes. In addition the intra-ventricular defibrillation electrode 13' is here in the form of a ring electrode which is of a cylindrical

configuration or elongated, with a porous surface, and the arrangement has a screw-in tip 15 at the distal end of the line and support legs 16 which can be controlledly spread out, directly distally in front of the defibrillation electrode 13'. Those means together ensure secure fixing of the electrode line and setting and approximate maintenance of a predetermined spacing of the electrode surface relative to the wall of the heart, even in the event of considerable physical activity on the part of the patient. To actuate the support legs in the context of implantation of the line, the arrangement has an actuating mechanism which is diagrammatically indicated in the Figure by the pull wire 16a.

Finally, the arrangement shown in Figure 2 does not have a separate extracardial surface electrode; it is replaced by a conducting surface of the defibrillator housing (which is not shown in the Figure). A combination with an additional surface electrode to afford a three-electrode arrangement (bipolar arrangement with reference electrode) is however also possible, whereby the production of the defibrillation field can be adapted in a particularly variable fashion to the anatomical and physiological factors involved in the case of a specific patient, that is to say the shock pulse field can be "focused" onto predetermined regions of the cardiac tissue.

Figure 3 diagrammatically shows a defibrillation electrode arrangement with a further modified electrode line 1" in accordance with a third embodiment of the invention. Once again the parts which are identical to those in Figure 1 are denoted by the same reference numerals as those used therein and will not be described once again hereinafter.

This line 1" only has a distal sensing or stimulation electrode, intended to be arranged in the ventricle, in the form of tip electrode 8 which is provided with a screw-in tip 15. The intracardial defibrillation electrode 13" which is here once again in the form of a ring electrode with a porous surface, of a cylindrical or elongated configuration, is disposed at a comparatively large spacing relative to the distal end of the line, that is

to say in the implanted condition is placed near the heart valve. The line 1" additionally carries, proximally from the two atrial electrodes, a second defibrillation electrode 17 which is in the form of a coil electrode and which after the implantation procedure is disposed in the vena cava superior 6. The five feed lines 1a" through 1e" are provided for the resulting total of five electrodes in the line 1". An additional extracardial feed line is also not required here, as in Figure 2.

The spatial arrangement of the defibrillation electrodes 13" and 17 makes it possible to generate a cardioversion field specifically in the region of the atrial cardiac tissue or the sinus node, which is advantageous in terms of terminating given kinds of tachycardia phenomena (for example atrial fibrillation).

Figures 4 through 6 each diagrammatically show respective portions of electrode lines 1A (Figure 4), 1B (Figure 5) and 1C (Figure 6) which belong to further defibrillation electrode arrangements in embodiments of the invention.

In the case of the line 1A shown in Figure 4 the arrangement has a plurality of separate defibrillation electrodes which are arranged in the form of segments of a cylinder around the line body and of which the electrode portions 13a through 13c can be seen in the drawing. Those separate electrodes are provided with separate feed lines so that they can be connected individually or in groups to the output of a defibrillator.

The line 1B shown in Figure 5 has six separate defibrillation electrodes 13a' through 13f' which are in the form of ring electrodes and which are also provided with separate feed lines so that they can be connected individually or in groups to the output of a defibrillator. As also in the case of the line 1A in Figure 4, line 1B makes it possible to provide for differentiated location and shaping of a shock pulse field without the necessity for that purpose to involve a plurality of feed lines and electrodes which have to be laid separately, as in known arrangements involving variable geometry for the stimulation pulse field.

The line 1C in Figure 6 substantially corresponds to the line 1' shown in Figure 2, with the essential difference that the support legs of which the Figure shows the legs 16A through 16C are angularly displaceable with respect to the body of the line whereby the position of the defibrillation electrode 13 can be more differentiatedly adjusted within the ventricle. That is advantageous in particular in the case of an embodiment without a screw-in tip in which the position of the electrode in the longitudinal direction of the ventricle can also be influenced by way of angular displacement of the support legs.

The invention is not limited in terms of its implementation to the embodiments set forth hereinbefore. On the contrary it is possible to envisage a large number of further modifications which can be afforded in particular by foregoing individual elements and/or other combinations of elements illustrated in various Figures in an arrangement.

Figures 8a through 8e show diagrammatic views illustrating the principle of variants of the connection of the individual electrodes of an electrode arrangement in accordance with an embodiment of the invention - more specifically the electrode line 1" shown in Figure 3 - with an implanted defibrillator 100 or combined defibrillator/cardiac pacemaker 100', which are intended by means of examples to illustrate the multiplicity of circuitry options which are appropriate for respective given conditions of use.

In Figure 8a the atrial electrodes 10 and 11 of the electrode line 1" are connected as sensing electrodes for the occurrence of tachycardial arrhythmia in a bipolar circuit to an input stage 101 of a defibrillator 100 which is connected at the output side to a control unit 102. That in turn is connected on the output side to an output stage 103 which, upon the detection of heart signals which indicate an arrhythmia situation which is to be terminated by a shock pulse, applies a suitable shock pulse - also in bipolar mode - to the cardiac tissue in the region of the atrium by way of the defibrillation electrodes 13, 17. In this case a conducting housing

surface 104 of the defibrillator housing can additionally act as a reference electrode REF and - depending on the respective position of the defibrillator relative to the heart - can perceptibly influence the field configuration. The ventricular tip electrode 8 is not connected here.

Referring to Figure 8b this tip electrode 8 and the housing electrode 104 (as the reference electrode REF) form a unipolar sensing arrangement for ventricular heart signals and the intraventricular defibrillation electrode 13 and once again the housing electrode 104 form a shock electrode configuration, which is also unipolar, for applying a cardioversion pulse which acts in the region of the right ventricle. The other electrodes are not used in this example.

As shown in Figure 8c the atrial electrodes 10 and 11 are connected as universal sensing electrodes for detection of the atrial heart action potentials as input signals for controlling a combined cardiac pacemaker/defibrillator 100' in a bipolar circuit to the input stage 101' thereof which at its output side is connected to a control unit 102' - which as will be appreciated is designed in accordance with the enlarged purpose of use of the apparatus. The control unit 102' is connected at the output side to a defibrillator output stage 103A' and a cardiac pacemaker output stage 103B' which in accordance with evaluation of the heart signals detected by way of the atrial electrodes 10, 11, supply as required pacemaker pulses or a cardioversion shock. The defibrillator output stage 103A' is connected in unipolar mode to the ventricular defibrillation electrode 13 while the vena cava electrode 17 in the case of cardioversion acts here as a reference electrode REF (D). A conducting surface 104' of the housing of the combination unit 100' and the proximal electrode 11 of the two atrium electrodes are connected to the outputs of the pacemaker final stage 103B' so that pacemaker pulses are outputted by way thereof .

Figure 8d shows a modification of this circuit which differs from the latter insofar as the vena cava coil 17, besides the distal atrium electrode 10, serves as a pacemaker electrode in a bipolar stimulation procedure.

Instead of the distal atrium electrode the proximal atrium electrode 10 can also be connected to the pacemaker output.

A further modification is shown in Figure 8e: here atrial pacemaker stimulation as well as detection of atrial heart actions for control of the pacemaker portion is effected by way of the two atrial electrodes 10, 11. In contrast a defibrillation shock for terminating ventricular fibrillation is outputted by way of the ventricular defibrillation electrode 13 in response to a ventricular tachycardia signal picked up by way of the ventricular tip electrode 8, in which case the unit housing 104' acts as a reference electrode REF (D).

In the event of additional use of a subcutaneous surface electrode (as shown in Figure 1), that electrode, besides use as a true third electrode involving independent potential, can also be electrically connected in parallel with respect to the vena cava coil 7 or the unit electrode 104 or 104'.

Corresponding and further alternative circuit configurations which the man skilled in the art can deduce on the basis of the fundamental notions of the invention are also possible for the other electrode configurations described hereinbefore and further electrode configurations which are within the scope of the claims. In particular it is readily possible to implement variants which permit both sensing of heart actions as input signals for a dual-chamber pacemaker and also the output of stimulation pulses thereof - besides the transmission of defibrillation pulses - by way of electrodes on a single electrode line, whereby the above-described concept of the single-line defibrillator is advantageously linked to that of the single-line dual-chamber pacemaker (which is known as such). Particularly suitable for that purpose is the arrangement shown in Figure 1 which, besides the ventricular defibrillation electrode has two ventricular sensing and/or pacemaker electrodes.

CLAIMS

1. A defibrillation electrode arrangement for connection to an implantable defibrillator (100; 100'), comprising at least one first defibrillation electrode (13; 13'; 13"; 13a-c; 13a'-f') arranged on an electrode line (1; 1'; 1"; 1A; 1B; 1C) to be positioned intracardially, and a second defibrillation electrode (14; 17), wherein the first defibrillation electrode is in the form of a cylindrical electrode or an electrode in the form of segments of a cylinder and is arranged at such a predetermined spacing from the distal end of the electrode line that after insertion of the electrode line it is disposed without touching the wall of the heart freely in a heart (2), in particular in the ventricle (3), and the second defibrillation electrode (14; 17) is arranged outside the ventricle in such a way that in the operating state of the defibrillator a defibrillation zone (D) which is in the form of strip or ring is formed in the wall of the heart, and in addition at least one sensing and/or pacemaker electrode (10, 11) is arranged on the electrode line in such a way that after insertion of the electrode line it lies in the atrium (3) of the heart.

2. A defibrillation electrode arrangement as set forth in claim 1 characterized in that the second defibrillation electrode is formed by an extracardially arranged surface electrode (14) or at least one portion (104; 104') of the housing of the implantable defibrillator (100; 100').

3. A defibrillation electrode arrangement as set forth in claim 1 characterized in that the second defibrillation electrode is formed by an electrode (17) which is of a coil configuration and which is adapted to be arranged in a blood vessel (7) near the heart and which in particular is arranged on the electrode line (1").

4. A defibrillation electrode arrangement as set forth in claim 3 characterized in that the third defibrillation electrode is an extracardially arranged surface electrode (14; 104; 104') which is formed in particular by a portion of the housing of the implantable defibrillator (100; 100'), wherein the first and second defibrillation electrodes (13, 17) are connected to outputs of the defibrillator and in the operating state thereof have different polarities in relation to the third electrode and the three defibrillation electrodes are spatially arranged relative to each other in such a way that produced between them is a spatially distorted dipole field with an increased potential gradient above the defibrillation threshold in a region of the wall of the heart with a defibrillator output voltage which is below the defibrillation threshold.

5. A defibrillation electrode arrangement as set forth in claim 4 characterized in that the first through third defibrillation electrodes are spatially arranged in such a way that the equipotential lines which are formed entail a maximum curvature in the region of the heart.

6. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that the electrode line (1C) has non-conducting spacer means (16; 16A, 16B, 16C) which support the electrode line against the wall of the heart after insertion into the ventricle.

7. A defibrillation electrode arrangement as set forth in claim 6 characterized in that the spacer means (16A, 16B, 16C) are extracorporally adjustable in such a way that the position of the first defibrillation electrode (13) is variable relative to the wall of the heart after insertion of the electrode line (1C).

8. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that at least one further electrode (8, 9) is provided in the distal end region of the electrode line (1; 1").

9. A defibrillation electrode arrangement as set forth in claim 8 characterized in that the distal electrode (8, 9) which in particular is in the form of a tip electrode is connected as a first and the first defibrillation electrode (13) is connected as a second ventricular sensing and/or pacemaker electrode to the defibrillator (100) or a combined pacemaker/defibrillator (100').

10. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that arranged proximally from the first defibrillation electrode (13; 13'; 13") on the electrode line at such a spacing with respect thereto are two further electrodes (10, 11) that after insertion of the electrode line said electrodes lie in the atrium (3), in particular in the upper region thereof.

11. A defibrillation electrode arrangement as set forth in claim 10 characterized in that at least one of the atrial electrodes (10, 11) is connected as a first sensing and/or pacemaker electrode to the defibrillator (100) or a combined pacemaker/defibrillator (100').

12. A defibrillation electrode arrangement as set forth in claim 11 characterized in that both atrial electrodes (10, 11) are connected as first and second sensing and/or pacemaker electrodes in a bipolar circuit to the defibrillator (100) or the pacemaker/defibrillator (100').

13. A defibrillation electrode arrangement as set forth in claim 11 characterized in that at least a portion (104; 104') of the housing of the unit is electrically connected as a sensing-reference electrode to the

defibrillator (100) or as a sensing and/or stimulation-reference electrode to the combined pacemaker/defibrillator (100').

14. A defibrillation electrode arrangement as set forth in one of claims 3 through 10 and claim 11 characterized in that the coil-shaped electrode (17) which is adapted to be arranged in the vessel (7) near the heart is connected as a sensing and/or pacemaker reference electrode to the defibrillator (100) or combined pacemaker/defibrillator (100').

15. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that the first defibrillation electrode has a plurality of mutually insulated electrodes (13a-13c; 13a'-13f') which can be individually connected to the defibrillator.

16. A defibrillation electrode arrangement as set forth in claim 15 characterized in that the electrodes are in the form of segments of a cylindrical configuration (13a-13c).

17. A defibrillation electrode arrangement as set forth in claim 15 characterized in that the electrodes are in the form of rings (13a'-13f') arranged in a row in the longitudinal direction of the electrode line (1B).

18. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that at least one of the electrodes (8 through 11, 13; 13', 13"; 13a-13c; 13a'-13f'), in particular the first defibrillation electrode, has a porous surface with a fractal surface structure such that the active electrode surface is larger by at least two orders of magnitude than the surface resulting from the basic geometrical shape of the electrode.

19. A defibrillation electrode arrangement as set forth in one of the preceding claims characterized in that the electrode line (1; 1'; 1") has

a curved portion (1.1) which in the operating state is disposed in the atrium and which has two limbs which meet at an acute angle at a point (12) and which respectively include an angle $\geq 90°$ with the adjoining portions of the electrode line.

20. A defibrillation electrode arrangement as set forth in claim 19 characterized in that the sensing and/or pacemaker electrode (10) is arranged substantially at the point (12) at which the limbs meet.

21. A defibrillation electrode arrangement as set forth in claim 19 or claim 20 characterized in that the curved portion (1.1) has means for producing a biasing effect which produces the curvature in the operating state and the effect of which is removed by the insertion of a guide wire (18) into the electrode line (1) whereby the electrode line is straightened, or occurs automatically upon a rise in temperature of the electrode line, in the body.

Abstract

A defibrillation electrode arrangement for connection to an implantable automatic defibrillator, comprising at least one first defibrillation electrode arranged on an electrode line to be positioned intracardially, and a second defibrillation electrode, wherein the first defibrillation electrode is in the form of a cylindrical electrode or an electrode in the form of segments of a cylinder and is arranged at such a predetermined spacing from the distal end of the electrode line that after insertion of the electrode line it is disposed without touching the wall of the heart freely in the ventricle of a heart, and the second defibrillation electrode is arranged outside the ventricle in such a way that in the operating state of the defibrillator a defibrillation zone which is in the form of strip or ring is formed in the wall of the heart, and in addition at least one sensing and/or pacemaker electrode is arranged on the electrode line in such a way that after insertion of the electrode line it lies in the atrium of the heart.

Figure 1